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SCIENCE 24

Module 1: Dynamics of Motion

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Science 24

Module 1

DYNAMICS OF MOTION

Distance Learning

Alberta EDUCATION

Science 24
Student Module
Module 1
Dynamics of Motion
Alberta Distance Learning Centre
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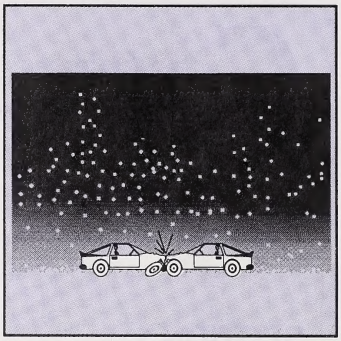

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OVERVIEW

Have you ever had an accident while riding your bike? You hit a rock you didn't see, or you went around a corner too fast and hit a patch of loose gravel. Before you knew it, you were flying one way and the bike was flying another way. The bike was dented and scratched, and your body was sore and your knees were scraped.

During accidents such as these, more than one type of collision is occurring. By understanding what happens in a collision, you can realize the danger involved in common activities such as driving a car or riding a bicycle. You can learn how to minimize the risks and danger involved by understanding the dynamics of motion. This module will consider motion from human, physical, and mathematical perspectives.

Module 1
Dynamics of Motion

Section 1
The Physics of It All

Section 2
It's the Sudden Stop That Kills

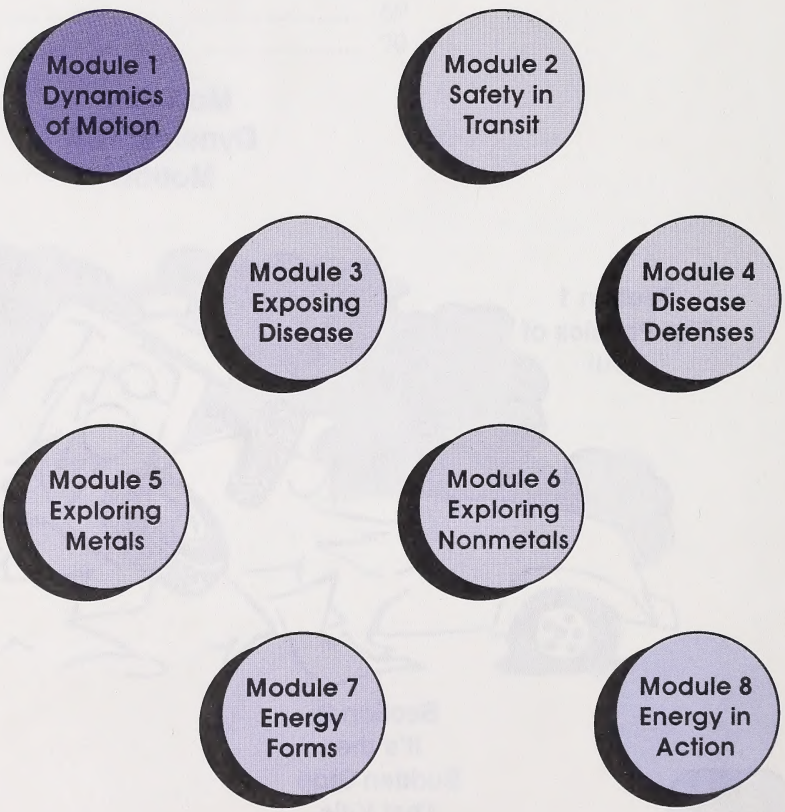
Section 3
The Mathematics of Motion

Evaluation

Your mark in this module will be determined by your work in the assignment booklet. You must complete all assignments. In this module you are expected to complete three section assignments. The mark distribution is as follows:

Section 1 Assignment	**24 marks**
Section 2 Assignment	**28 marks**
Section 3 Assignment	**48 marks**
TOTAL	**100 marks**

Course Overview



1 The Physics of It All

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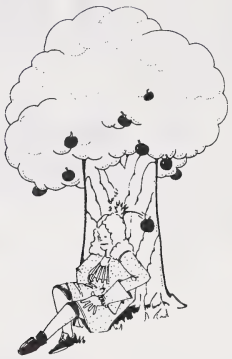
Have you ever seen a car that was involved in a car crash? Sometimes the metal is twisted and bent out of shape, or sometimes part of the car is not even there. When you look at a car that has been in a crash like this, have you ever wondered what happened to the occupants of the car?

Physics, which deals with matter and energy in terms of motion and force, will help you answer that question. In this section you will investigate some very important laws of motion. These laws will also help to explain what happens to the occupants of a car during a crash.

Activity 1: Newton's First Law



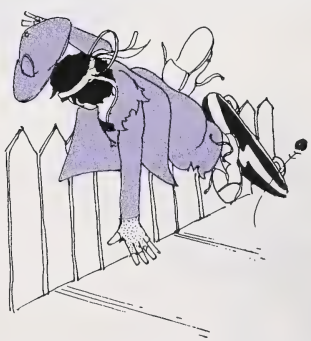
Sir Isaac Newton, an English physicist, discovered many very important principles about moving objects during the late 1600s. His work was so important that his observations have been made into scientific laws and are named after Newton.

inertia – the tendency of an object to resist changes in motion
The greater the mass, the greater the tendency to remain in motion or at rest.

Newton's first law is often referred to as the law of **inertia**. For moving objects, the law states the following:

An object in motion remains in motion, moving at the same speed and direction unless acted upon by an outside **force**.

force – a push or a pull that tends to change the position or motion of an object

Newton's First Law Put to the Test	
An object in motion remains in motion, moving at the same speed and direction,	unless acted upon by an outside force.
	

Investigation: Investigating Sudden Stops

In this investigation you will demonstrate what happens to the passenger of an automobile during an abrupt stop.

Materials You Need

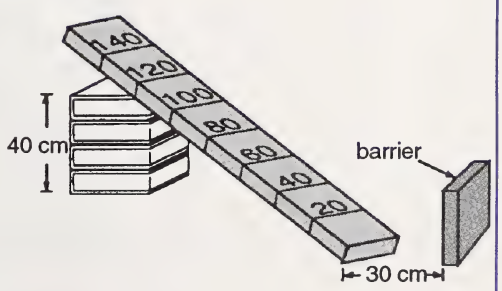
- wood or metal ramp about 1.5 m long and 30 cm wide
- any small toy car, preferably metal
- passenger represented by a cube about 2 cm on each side made from modelling clay, plastic putty, or a homemade substitution
- stack of books about 40 cm high
- metric ruler or tape measure
- chalk or erasable marker
- small board to act as a wall or barrier
- masking tape
- table or floor about 2 m × 2 m in area

Note: To make the substitution, combine 250 mL flour, 125 mL salt, 250 mL water, and food colouring.

Steps to Follow

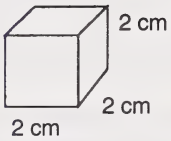
STEP A

Using chalk or a marker, mark off 20-cm intervals on the ramp. Tape the barrier firmly to the floor or table approximately 30 cm from the ramp. Place the end of the ramp on a stack of books as shown in the diagram.



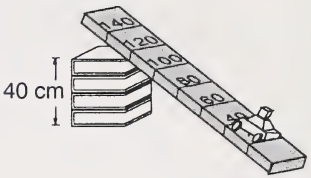
STEP B

Make a clay cube with the sides approximately 2 cm in length.



STEP C

Place the cube, very lightly, on the roof or hood of the toy car. Line up the front wheels of the car immediately behind the 20-cm mark on the ramp.

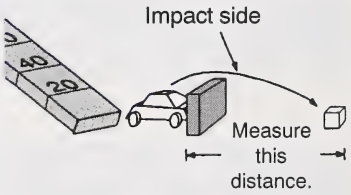


STEP D

Release the car and watch what happens to the clay cube immediately after the impact.

STEP E

Using chalk, mark where the cube comes to a stop. Using your ruler, measure the distance the cube travelled.
Note: Measure from the side of the barrier the car collided with.



STEP F

Repeat the experiment for two more trials at the 20-cm mark, and record your results in the table provided. Calculate the average of three trials from the 20-cm mark. If your results for each trial were 15 cm, 13 cm, and 14 cm, you would calculate the average by finding the total and dividing by 3.

Average = (15 cm + 13 cm + 14 cm)/3
= 42 cm/3
= 14 cm

STEP G

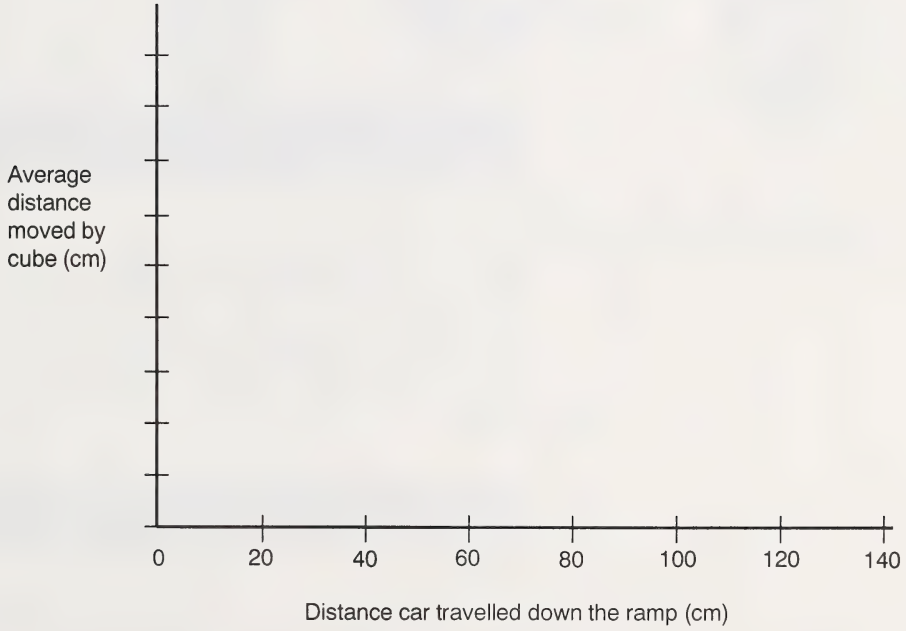
Repeat steps C through F for each distance shown in the table.

Observations

Distance from End of Ramp (cm)	Trial 1	Trial 2	Trial 3	Average Distance Travelled (cm)
20				
40				
60				

Conclusions

1. Complete the following graph using the data from your table.



2. Predict how far the cube would be thrown if the car was released from the 120-cm mark. (Hint: Use your graph to help you make your prediction). Try releasing the car from the 120-cm mark and compare the result with your prediction.

_____

_____

_____

_____

_____

3. How does the speed that the car travels affect the distance the cube was thrown?

_____

_____

_____

_____

Check your answers by turning to the Appendix, Section 1: Activity 1.

Did you ever get on a bus and have to stand in the aisle because all the seats were occupied? Do you recall what happened to your stance or balance as the bus began to move or when the bus stopped suddenly? Newton's first law is not solely restricted to moving objects. It also includes stationary objects or objects that are at rest. The law referring to stationary objects is stated in part as follows:

An object at rest remains at rest unless acted upon by an outside force.

Investigation: The Physics Behind the Magic

Have you ever seen anybody pull a tablecloth from a completely set table without having anything fall or hitting the floor? It can be done, and Newton's law may help to explain it.

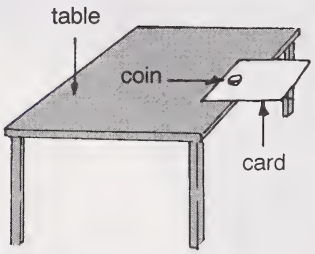
Materials You Need

- coin
- playing card
- table top

Steps to Follow

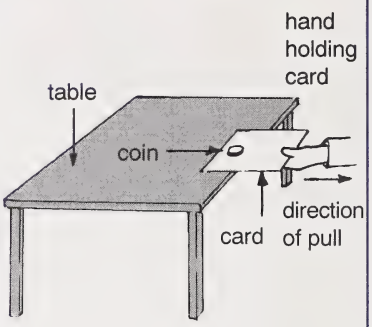
STEP A

Place the playing card on the table top with half of it hanging over the edge. Place the coin on the middle of the card.



STEP B

Pull the card out very slowly.

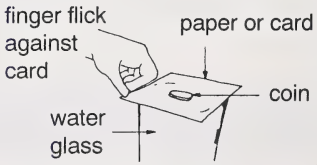


STEP C

Repeat the procedure, but this time pull the card out with a very short quick pull. Record what happened during each attempt in your observation table.

STEP D

As an additional challenge, repeat the same experiment using the rim of a drinking glass instead of a table stop. By flicking the card with your finger, try to remove the card (or strip of paper) from under the coin while it is balanced on the rim of a drinking glass.



Observations

Record what happened during each attempted pull. State what happens to the coin in each trial.

Trial	Pull Slowly	Pull Quickly
1		
2		
3		
4		
5		
6		
7		
8		

Conclusion

4. Explain why you observed different results when the card was pulled slowly compared with when the card was pulled quickly.

_____

_____

_____

Check your answers by turning to the Appendix, Section 1: Activity 1.

Activity 2: The Second Collision

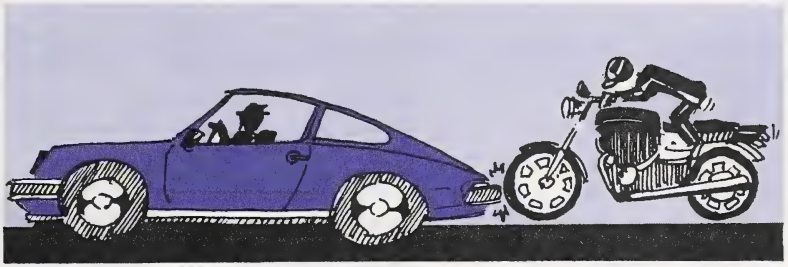
Newton's first law is very important when considering what happens to the passengers of a car in a collision.

In a car accident involving a rear-end collision, the occupant of the moving car will continue to move in the direction the car was going before the collision. The occupant of the stationary car remains stationary until a force is applied.

When a force is applied by a moving car to a stationary one, the stationary occupant will absorb some of the energy exerted by the force of collision and could end up with whiplash. The driver of the moving car could hit against the windshield, steering wheel, or dashboard. The injuries received by both of these occupants are due to their inertia.

Because the occupants inside the vehicles are not wearing seatbelts, they bounce around and are thrown against the steering wheel, windshield, or other obstacles. This movement is called the second collision. The colliding of the cars is considered to be the first collision. Most injuries result from second collisions.

Use this diagram to answer the following questions.



1. What action in the diagram illustrates the first collision?

_____

_____

2. Suggest a possible second collision that the motorcyclist may experience.

_____

_____

3. In which direction will the motorcyclist be thrown? Why?

_____

_____

_____

_____

4. In which direction will the driver of the car be thrown? Why?

_____

_____

_____

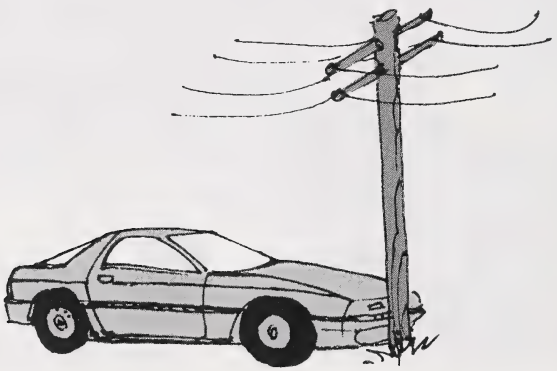
Check your answers by turning to the Appendix, Section 1: Activity 2.

Activity 3: Newton's Second Law

In a sense, Newton's first law is limited in that no outside forces act on an object. In reality, however, outside forces almost always act on an object. These outside forces are taken into consideration in Newton's second law which states the following:

> The change of motion of a body is directly proportional or dependent to the outside force being applied on the object.

This law simply means that a small force applied to an object will produce a small change in motion. A larger force produces a larger change in motion.



A car collides with a telephone pole and stops abruptly due to the large force exerted by the pole.

A car collides with a wooden fence and only slows down. The wooden fence exerts a small force.

Investigation: The Force Required to Change Motion

In this investigation you will demonstrate Newton's second law by showing that an object of greater mass requires a greater force to change its motion.

Materials You Need

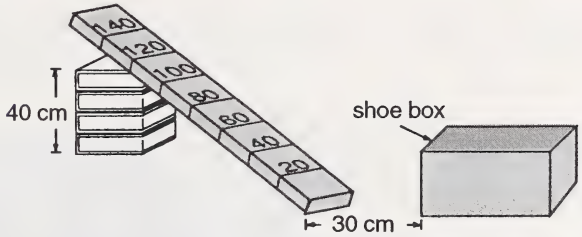
- wood or metal ramp about 1.5 m long and 30 cm wide, marked in 20 cm intervals
- stack of books approximately 40 cm high
- two toy cars of varying mass (284 mL and 400 mL cans of soup or other food could be used instead)
- empty shoe box
- metric ruler or tape measure

mass – a measure of the quantity of matter contained in an object, measured in grams or kilograms

Steps to Follow

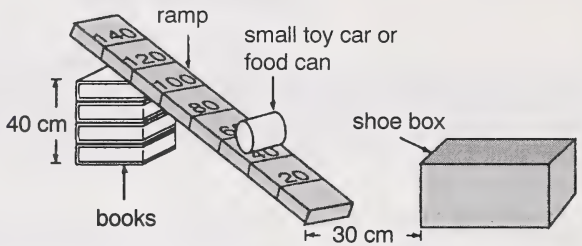
STEP A

Place the end of the ramp on a stack of books. Place the box approximately 30 cm from the end of the ramp as in the diagram. Do not fasten the box down to the floor or table. Place a mark on the floor or table where the box is originally placed.



STEP B

Place the small car or can at the 20-cm mark and roll it down the ramp. Measure the distance the box moved and record the results in the observation table.



STEP C

Repeat two more trials with the small car or can from the same distance. Calculate the average distance the box moved. Perform exactly the same experiment with the larger car or can and record the results.

STEP D

Repeat steps B and C from the distances shown in the table.

Observations

Car or Can	Distance travelled down ramp	Distance box moved			
		Trial 1	Trial 2	Trial 3	Average
small	20 cm				
small	30 cm				
small	40 cm				

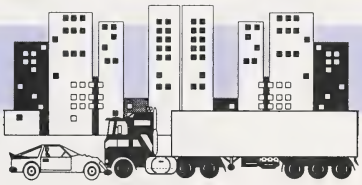
Car or Can	Distance travelled down ramp	Distance box moved			
		Trial 1	Trial 2	Trial 3	Average
large					
large					
large					

Conclusions

1. How did the mass of the car or can affect the distance the box was moved?

2. Using your results, state which car or can exerted more force.

3. Using the following diagram, explain which vehicle will experience the greatest change in motion. Explain why.



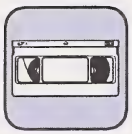
Check your answers by turning to the Appendix, Section 1: Activity 3.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Newton's laws are the main concepts in this section. An object in motion or at rest will remain that way unless an outside force acts on it. Also, the larger the mass of an object, the more force that will be required to change its motion.



To review Newton's first law of motion, do either Part A or Part B. In Part A you view the View TV Ontario video, *Inertia.* Part B involves doing the investigation: The Inertia of a Cork.

Part B

Investigation: The Inertia of a Cork

In this investigation you will see how Newton's laws explain the motion of a cork suspended in water.

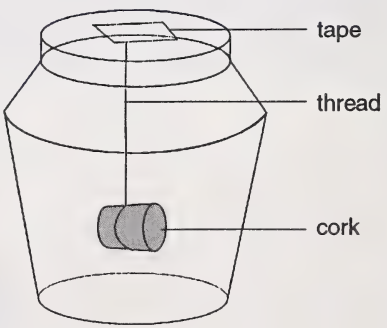
Materials You Need

- cork
- tape
- thread
- wide-mouth jar with lid

Steps to Follow

STEP A

Measure a length of thread to match the height of the wide-mouth jar. Tie the thread around a cork and with tape fix the thread to the bottom of the lid. Screw the lid on the open-mouth jar.



STEP B

Push the glass jar along the surface of the table and observe the cork.

OBSERVATION

1. In which direction does the cork move?

_____

_____

_____

_____

STEP C

Place your left hand about 50 cm in front of the jar. Push the jar with your right hand until it strikes your left hand and observe the movements of the cork.

OBSERVATION

2. In which direction does the cork move?

_____

_____

_____

_____

STEP D

Hold the jar in both hands, extend your hands outward, and swing the jar around by turning around in a circle.

OBSERVATION

3. In which direction does the cork move?

_____

_____

_____

_____

Check your answers by turning to the Appendix, Section 1: Extra Help.

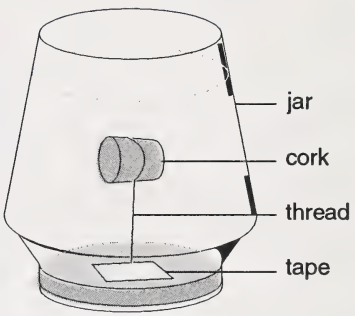
To explain Newton's second law, consider a large bus and a small toy car. Which of these would require a larger force to make them move? The larger the mass of an object, the greater the force required to move it.

Enrichment

Things are not always what they appear to be. Magicians often use special situations to make things happen in unexpected ways. You can do the same thing with your cork in a jar. Think about Newton's laws; use these laws to explain what you see.

STEP A

Fill the jar you used in the Extra Help investigation with water, and tightly screw on the lid. Turn the jar upside down so that the cork hangs suspended in the water.



STEP B

Push the glass jar along the surface of the table and observe the cork.

OBSERVATION

1. In which direction does the cork move?

_____

_____

_____

_____

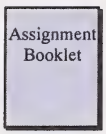
STEP C	OBSERVATION
Push the jar with one hand and then stop it with the other hand.	2. In which direction did the cork move? _____ _____ _____ _____

STEP D	OBSERVATION
Hold the jar very firmly in both hands, extend your arms, and swing the jar around by turning around in a circle.	3. In which direction does the cork move? _____ _____ _____ _____

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

An object at rest will stay at rest unless an outside force acts on it. Similarly, an object in motion will stay in motion unless an outside force acts on it. The force produced by an object depends upon its mass. The greater the mass of the object, the greater the force that it can produce.



ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 1.

It's the Sudden Stop That Kills

[1]

Have you ever heard of a skydiver whose parachute failed to open? It wasn't the fall that hurt, it was the sudden stop.

This occurs in car collisions also. Why does the race car driver get injured in a crash? The car is involved in the collision. Then the driver is involved in a crash with the inside of the car. This second collision between driver and car often involves hitting a windshield, steering wheel, or dashboard.

In this section you will consider reducing the impact of the second collision by using safety devices in automobiles. You will design a life-saving package to reduce personal risks.

[1] *The Edmonton Journal* for the photo by Greg Southam from September 2, 1990, page F8. Reprinted by permission of *The Edmonton Journal*.

Activity 1: Eliminating the Second Collision

Investigation: Safe Packaging

A second collision occurs when the occupant of a motor vehicle is thrown against a hard surface in the car's interior. In this investigation you will design a package that will protect an egg from breaking in a major collision. The empty milk carton or similar small box will act as the car in this investigation, and the egg will be the occupant. You actually will be trying to eliminate the seond collision.

Materials You Need

- raw egg
- empty 2 L milk carton or any similar type of small box
- any materials that could help to eliminate the risk of injury during a second collision (suggested materials could include the following items: popcorn, crumpled newspaper, cloth, cereal, fibreglass insulation, gelatin, chocolate pudding, water, polystyrene, marshmallow, cotton batting)

Steps to Follow

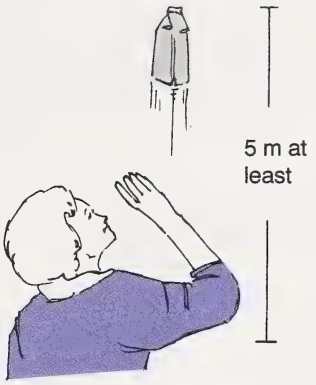
STEP A

Using any selected materials that you feel will protect the egg from breaking in the fall, package the egg inside the milk carton or box. Keep the egg and all materials used inside the milk carton.

STEP B

When you are sure that the egg will survive a major collision, go to an outside area with a hard surface such as concrete or pavement. You should select an area that has at least 10 m of overhead clearance.

Throw the package up into the air as high as you can. Try to get at least 5 m of height.



STEP C

Carefully remove the egg from the carton to assess your success or failure.

STEP D

If your design was not successful, re-design your package, and repeat the investigation. Make whatever changes you think are necessary to achieve success. You could modify the container or materials.

Observations

1. Briefly describe the condition of your egg.

2. If you re-designed your package, how did the results of the second trial compare with the results of the first trial? Why?

Conclusions

3. If your egg survived, state why it did so. If your egg was broken, state why you think it broke.

4. Was the second collision eliminated? How can you tell?

Check your answers by turning to the Appendix, Section 2: Activity 1.

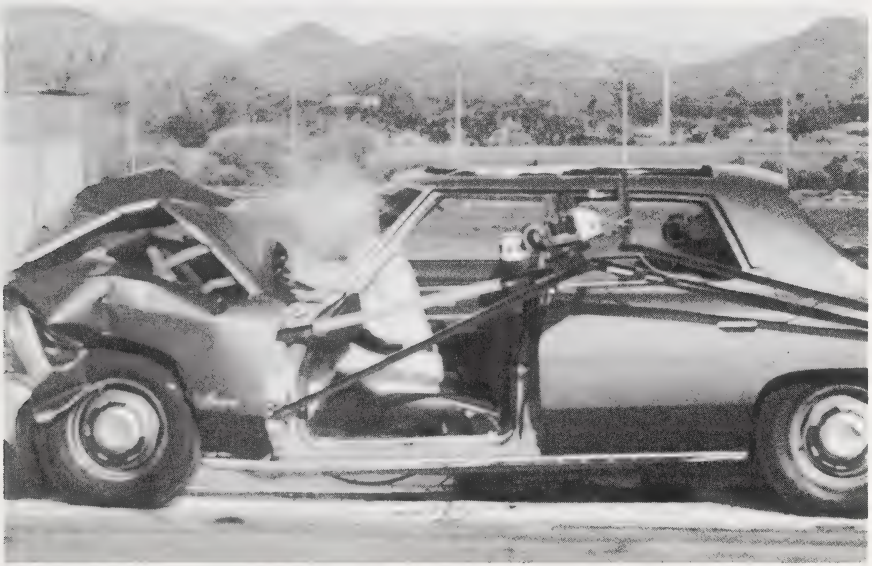
Preventing the Human Collision

simulation – an imitation of the real thing

There are many ways to save an egg from breaking when it is dropped on a hard surface from a height. The investigation that you conducted in trying to save the egg from breaking is considered to be a **simulation**. The egg in the carton simulates a person in a car.

Engineers use simulations to test safety devices when designing automobiles. The main difference between your simulation and that of engineers is in the materials used. The principles are still the same.

Extensive research and testing are essential if the second collision is to be avoided. Design engineers and technicians test and re-test different technologies designed to save lives during collision.



[1]

Actual cars and safety devices are used during testing where realistic collision situations are simulated. The car is then analysed for any breaks, damage, and stress points. It is often repaired and retested several times before safety features are built into vehicles by car manufacturers.

[1] Transport Canada and the Ontario Ministry of Transportation and Communications, *The Human Collision, 1976*. Reproduced with the permission of the Minister of Supply and Services Canada, 1992.

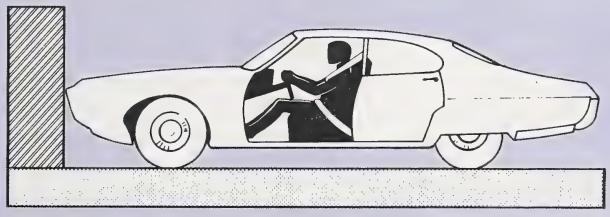
Dummies, or models resembling humans, ride in crash simulator sleds moving at different speeds. These sleds will suddenly stop against a solid barrier. Slow-motion photography and instruments inside the dummy record the effect of such an impact on various body parts.

1

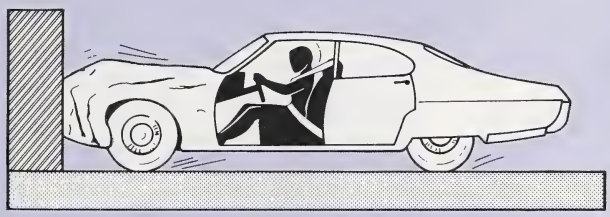
Such testing has resulted in improved interior designs and restraining devices such as seat belts and air bags. These tend to increase the time of impact in a collision or to distribute the force of input over stronger parts of the body. Second collision injuries have been greatly reduced but not eliminated.

[1] Transport Canada and the Ontario Ministry of Transportation and Communications, *The Human Collision, 1976*. Reproduced with the permission of the Minister of Supply and Services Canada, 1992.

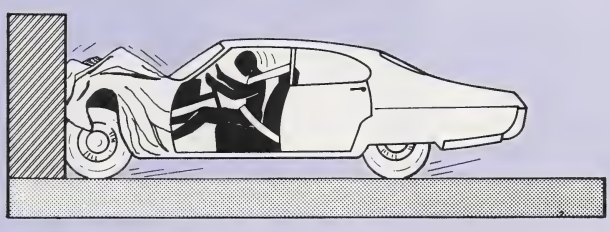
Seat Belts Prevent Second Collision



On impact, the car begins to crush and to slow down.



As the car slows down, the person moves forward until the seat belts restrain him. The belts keep him in his seat and keep his head and chest from striking the car interior.



Being fastened to the framework of the car, belted occupants are able to "ride down" the collision as part of the car. They are able to take advantage of the car's slower stop, as it crushes and absorbs energy.

[1]

[1] Transport Canada and the Ontario Ministry of Transportation and Communications, *The Human Collision, 1976*. Reproduced with the permission of the Minister of Supply and Services Canada, 1992.

Activity 2: Safe Packaging in Automobiles

People must be safely packaged in automobiles to prevent them from hitting some part of the car during a collision.

At 50 km/h, a head-on collision with a stationary object can generate the same amount of force as jumping from a third-story window.

[1]

Investigation: Safe Packaging in Automobiles

In this investigation you will model some of the safety features of an automobile.

Materials You Need

- an empty 1 L milk carton
- 2 cm × 4 cm dummy made from modelling clay
- 30 cm × 10 cm small board to act as a barrier
- smooth surface such as table top or floor
- thread
- two shoelaces
- balloon

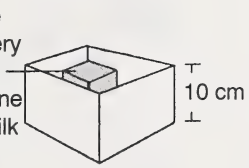
---

[1] Transport Canada and the Ontario Ministry of Transportation and Communications, *The Human Collision, 1976*. Reproduced with the permission of the Minister of Supply and Services Canada, 1992.

Steps to Follow

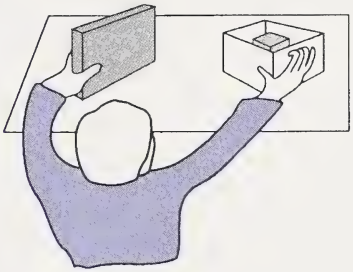
STEP A

Cut the bottom 10 cm off a 1 L milk carton. Make a 2 cm × 4 cm dummy from modelling clay, and very gently place it against one side of the carton.



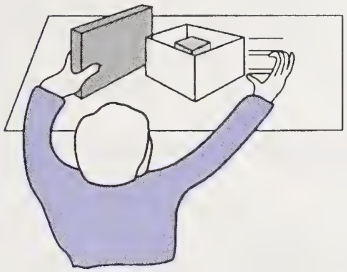
STEP B

Place the milk carton on the smooth surface. Hold the barrier in place with one hand and in the other hand have the milk carton ready to slide.



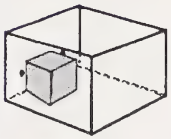
STEP C

Slide the milk carton into the barrier. Observe and record what happens to your passenger.



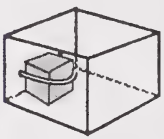
STEP D

Smooth the sides of the dummy if it is marked or dented, and place it back into the carton. Make a small hole in the milk carton on either side of the dummy with a pencil or pen.



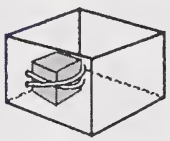
STEP E

Take the thread, and tie a lap belt around the dummy. Repeat step C, and record what happens.



STEP F

Smooth out the dummy again. This time use shoelaces to make a lap belt and shoulder harness. You will have to make another hole to put the laces through.



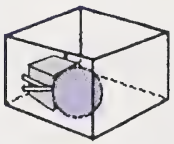
Use shoelaces to make the lap belt and shoulder harness.

STEP G

Repeat step C and record your observations.

STEP H

Place an inflated balloon between the dummy and the carton, and repeat step F. Make sure that there is not too much air in the balloon. Repeat step C, and record your observations.



Put the inflated balloon between the harnessed dummy and the opposite wall of carton.

Observations

Situation	Visible Effects on the Chevy Dummy
dummy is free to move	
dummy held in with thread	
dummy held by shoe lace lap belt and shoulder belt	
dummy held by lap belt, shoulder belt, and air bag	

Conclusions

1. What happened to the dummy when it was not tied in by anything?

_____

_____

2. What was one disadvantage about using the thread seat belt?

_____

_____

3. Which type of seat belt system provided the greatest protection to the passenger – a lap belt or a lap belt and a shoulder belt?

_____

_____

4. What was the function of the balloon in this investigation?

_____

_____

Check your answers by turning to the Appendix, Section 2: Activity 2.

In the investigation just completed you should have discovered that if the second collision is eliminated, the lives of passengers in an automobile could be saved during a collision.

Like the automobile engineers, you also used simulations in your testing. The thread and shoelaces represented seat belts, and the balloon acted as an airbag. The use of airbags in cars has been steadily increasing with successful results.

Research and laboratory testing have shown that seat belt systems and airbags save lives. Studies made at the scene of accidents and investigation of accident records have also contributed to the development of safety features built into the modern automobile.

Activity 3: Transportation Safety

Do you know anyone that became an innocent traffic statistic because of an impaired driver?

Have you ever seen anyone criticize other drivers on the road when their own driving skills are questionable?

No amount of extensive research, testing, or technological modifications by car manufacturers can achieve total transportation safety. All drivers face occasional road hazards and personal risk. Some hazards are beyond the driver's control.

1. What hazards can you think of that might be beyond the driver's control?

hydroplaning – riding on a film of water collected between tires and the road surface under special conditions

A special road hazard known as **hydroplaning** occurs at higher speeds when the road is wet with snow or rain and tire treads are no longer effective.

Water builds up between the tires and road surface. This prevents direct contact between them, causing the tires to ride on a film of water. The driver could lose control of the vehicle without warning due to unexpected skidding and loss of traction.

2. Suggest two ways in which loss of vehicle control due to hydroplaning can be prevented.

3. Winter driving on the Canadian prairies presents a unique challenge for most drivers. Suggest four environmental or natural conditions that are hazardous to winter driving, and briefly explain why they are hazardous.

4. Suggest four environmental or natural conditions that are hazardous to summer driving, and briefly explain why they are hazardous.

5. Suggest four ways in which the actions of other drivers or unexpected circumstances could become a risk to your own safety.

Other Modes of Transportation and Safety

Have you ever driven a motorcycle, snowmobile, moped, or motor bike?

Other than cars as a means of transportation, most people don't tend to think about planes, trains, motor boats, buses, trucks, and other modes of travel.

Just like automobiles, other types of transportation also involve certain degrees of personal risk.

Use the following tables showing the number of casualties versus the mode of transportation involved to answer the questions.

Types of Vehicles Involved in Casualty Collisions* 1990

	Vehicles in Fatal Collisions		Vehicles in Non-Fatal Injury Collisions		Total Vehicles in Casualty Collisions	
Type of Vehicle	N	%	N	%	N	%
Passenger Car	276	46.9	14107	63.2	14383	62.7
Pickup Truck/Van	203	34.5	5794	25.9	5997	26.2
Motorcycle	16	2.7	619	2.8	635	2.8
Bicycle	12	2.0	609	2.7	621	2.7
Truck 4000 kg+	33	5.6	493	2.2	526	2.3
Tractor-Trailer	39	6.6	422	1.9	461	2.0
Other Bus	1	0.2	129	0.6	130	0.6
School Bus	1	0.2	40	0.2	41	0.2
Off Highway Traffic	4	0.7	30	0.1	34	0.1
Farm Equipment	1	0.2	20	0.1	21	0.1
Other	3	0.5	74	0.3	77	0.3
Total Number of Vehicles	589	100.0	22337	100.0	22926	100.0

* Based on those cases where type of vehicle was specified on the collision report form.

[1]

6. According to the previous table, passenger cars and pickup trucks/vans accounted for almost 90 percent of the total casualty collisions compared with about 5 percent for motorcycles and bicycles. Suggest why there are fewer motorcycle casualty collisions than there are passenger vehicle casualty collisions.

_____

_____

_____

[1] Excerpts from *Alberta Traffic Collision Statistics, 1990.* Reprinted by permission of Alberta Transportation and Utilities.

U.S. Transportation Accident Passenger Death Rate, 1988
Source: National Safety Council

Kind of Transportation	Passenger Miles (billions)	Passenger deaths	Rate per 100 mln. pass. miles	1986-1988 aver. death rate
Passenger automobiles and taxis[1]	2,143.9	25,614	1.19	1.23
Buses	127.9	44	0.03	0.03
Intercity buses	23.1	6	0.03	0.03
Railroad passenger trains	12.8	2	0.02	0.06
Scheduled airlines	334.2	273	0.01	0.03

[1] Drivers of passenger automobiles are considered passengers.

NATIONAL SAFETY COUNCIL

7. Using the information from the previous table, which modes of transportation, in terms of the same number of passenger miles, are the safest? Which are least safe?

_____

_____

_____

_____

8. There are about six times as many car fatalities in the United States as in Canada. What other information would be needed to compare the fatality rate between the two countries?

_____

_____

_____

Check your answers by turning to the Appendix, Section 2: Activity 3.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

The first collision involves a vehicle crashing into another object such as another vehicle, pole, tree, or house. Sometimes human error causes accidents; sometimes mechanical problems cause accidents. The second collision involves a passenger of a vehicle striking interior parts of the vehicle. Hitting one's head on the dashboard or windshield, breaking ribs on the steering column or door handles, and being struck by loose items inside the vehicle are just a few examples of the second collision.

1. What does the term *second collision* mean?

   _____

   _____

2. Give four technologies developed to reduce the second collision.

   _____

   _____

   _____

   _____

3. Try to think of two ways that vehicles are made to reduce the impact of the first collision.

   _____

   _____

   _____

   _____

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Do **one** of the following:

1. Go back to Activity 1 and design an alternative restraint and test it.

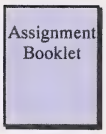
2. Design a car and illustrate the safety features that are specifically designed for passenger safety.

3. Research and write a report on child restraints. The body of an infant is different and more fragile than the body of an adult. Find out how a child's body is protected in a collision.

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

The first collision in an automobile accident is the car making contact with another object. The second collision refers to the contact made between the occupants of the car and the car's interior as the occupants are thrown against the interior during a collision. Eliminating the second collision is the main goal in automotive safety design.



ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 2.

Section

3 The Mathematics of Motion

WESTFILE INC.

Do you remember ever seeing or hearing a story about an evil villain tying an innocent victim to the railroad tracks and then waiting for the train to run over the victim. The engineer sees the person tied to the tracks and slams on the brakes. Will the train be able to stop in time?

Why is it that it takes a train so long to stop? In this section you will learn about the mathematics of motion. You will discover different types of energy, and learn about how momentum applies to moving objects.

Activity 1: Kinetic and Potential Energy

Have you ever complained about how hard you worked on some activity and how little energy you had left?

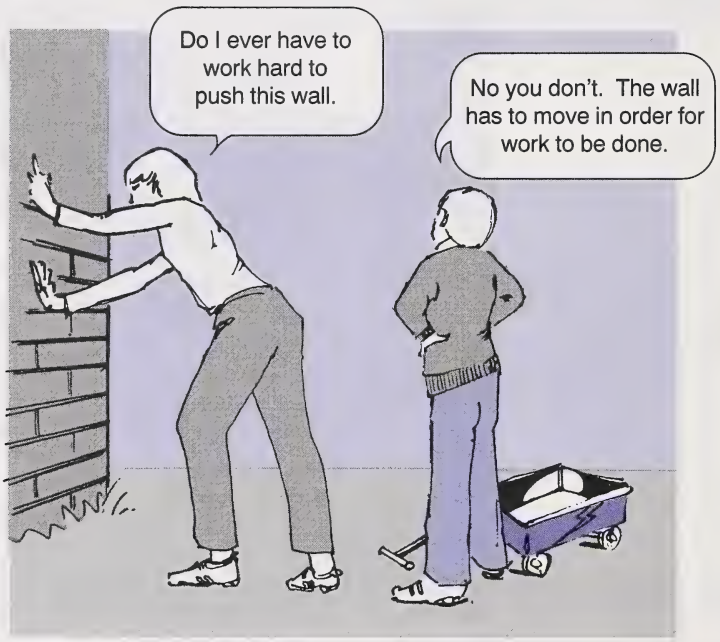
In this activity you will consider the words *energy* and *work* in a somewhat different manner.

energy – the capacity to do work

Energy is defined as the ability or capacity for doing work. But what is work?

work – a force applied to an object over a certain distance

Work is defined as a force applied to an object over a certain distance. Recall that force is simply a push or pull that tends to change the position or motion of an object.



This means that an object must be in motion in order for work to be done on it. Therefore, unless the wall moves, the person pushing on the brick wall is not doing work; whereas the person pulling on the wagon is doing work.

The energy required to do work will fall into two basic forms: potential energy and kinetic energy. To distinguish between the two types of energy, you will do the following investigation.

Investigation: Potential and Kinetic Energy

In this investigation you will distinguish between potential and kinetic energy.

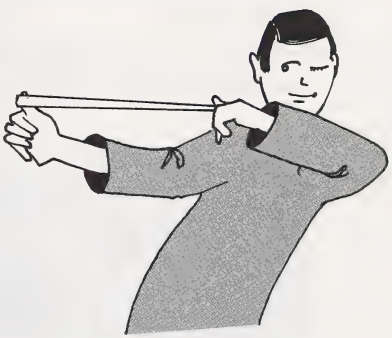
Materials You Need

- elastic band

Steps to Follow

STEP A

Make a fist with one hand, but leave your thumb sticking straight up. Take the elastic band and loop one end over the tip of your thumb. Stretch the other end back towards yourself.



At this point, the elastic band is not yet moving. However, it has the ability to do work if released, and is therefore said to possess energy. Due to its position, this energy is referred to as **potential energy**.

potential energy – stored energy or the energy of an object due to its position

STEP B

Release the end of the elastic that is closest to you. Write a brief sentence that describes what happens.

OBSERVATION

1. Briefly describe what happened when you released the elastic band.

kinetic energy – energy of an object due to its motion

After you released one end of the elastic band, it should have flown through the air. At this point, the elastic band has what is called kinetic energy. All moving objects possess **kinetic energy**.

Conclusions

2. When you stretched the elastic and held it motionless, was the elastic doing any work on your finger as you were ready to shoot it? Explain.

3. When you let the elastic go, there was a small period of time when the elastic pulled its stretched end back to your thumb. Was it doing any work during this time? What was it doing work on? Explain.

Check your answers by turning to the Appendix, Section 3: Activity 1.

Forms of Energy

When you stretched the elastic, you did work on it to move it to a new position. The energy it now has is known as potential energy.

Potential energy can also be considered as a form of stored energy. In most cases, potential energy exists because work has been done on an object to move it to a new position.

Kinetic energy is the energy of motion. Moving objects, such as wind or a moving vehicle, possess kinetic energy. Potential energy can be converted into kinetic energy. Also, kinetic energy can be converted to potential energy.

Without an energy source, automobiles would be useless. They are energy-dependent and could also be thought of as energy-converting machines. The following diagrams may help to illustrate how potential energy is changed into kinetic energy in an automobile.

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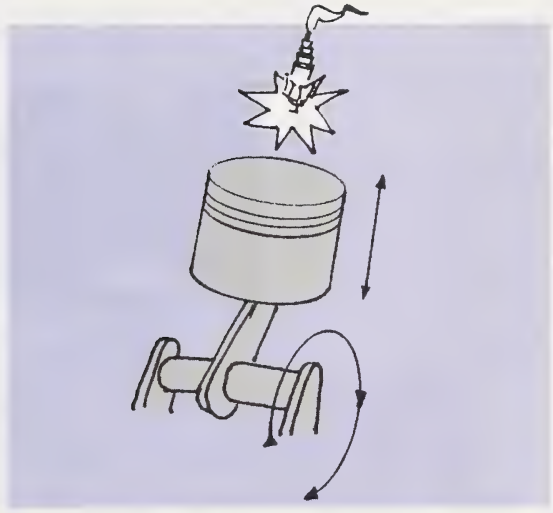
Energy is stored in the gasoline going into the car. It is known as chemical energy, a form of potential energy.



The chemical energy is converted into heat energy and work being done on moving engine parts.

Automobiles are very inefficient users of energy. Although all of the energy can be accounted for, only a small amount, about 25 percent, of the energy consumed is converted into kinetic energy which actually makes the car go. Most of the energy in the gasoline is converted into heat and sound energy. The large waste of energy by cars is one reason why the research into producing energy-efficient cars continues.

Law of Conservation of Energy

Does energy get used up when it is converted from one form to another?

To answer that question, careful measurements were made over a very long period of time, indicating that energy does not get used up.

Since energy can neither be created nor destroyed, but it may be converted from one form to another, it is said to be conserved or constant. This concept is referred to as the **law of conservation of energy.**

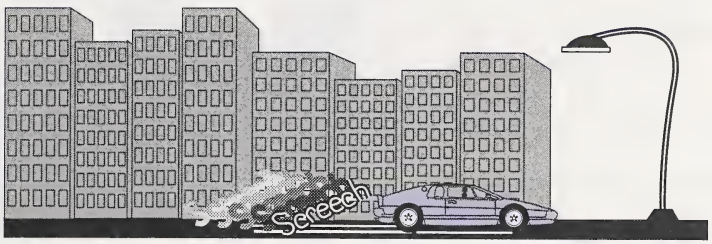
law of conservation of energy – a law stating that energy cannot be created or destroyed

This law can also be applied to a car crash. You can trace the energy conversions in a collision using the following sequence of diagrams:

Diagram 1

When a car moves, it has kinetic energy which comes from the conversion of potential energy in gasoline. Work is done as the gasoline molecules are rearranged inside the engine parts.

Diagram 2



When the car suddenly brakes, the tires exert a force through distance on the road. The car heats the road by using some of the car's kinetic energy to create tire skid marks. Since the car is "spending" some of its kinetic energy, it slows down.

Diagram 3

Not only is some of the car's kinetic energy used to leave tire skid marks, heat and sound are also produced as the car hits an obstacle. Energy is also needed for work to be done as the car slows down and begins to crush.

Diagram 4

Since work is done in forcing the metal through a distance, energy is required. Some of the car's kinetic energy was "spent" doing this. Since the car lost kinetic energy, it slows down even more.

Diagram 5

Since the car lost some of its kinetic energy, it slowed down. The occupants continue to move at the original speed due to their inertia. If they were wearing a seat belt, the seat belt would do work on them, take some of their kinetic energy, and slow them down. Without a seat belt, the steering wheel, windshield, or dashboard would do work on them. These objects would concentrate the force and do more harm to the occupants.

The accident sequence illustrated in the diagrams shows how energy is not lost or gained. However, it is changed into another form such as heat or sound, or it is transferred to other objects.

Answer the following questions about energy.

4. Assume a car is parked on top of a hill. Does the car possess more or less potential energy than a car at the bottom of a hill? Explain.

_____

_____

_____

5. In a car crash, such as when a car collides with a power pole, is all of the energy transferred to the pole? Explain.

_____

_____

_____

Check your answers by turning to the Appendix, Section 3: Activity 1.

Activity 2: Momentum of Crashing Vehicles

If a semi-trailer truck and mosquito were both travelling at 20 km/h towards you, would you react in the same way to both? You would probably try to avoid the truck from hitting you. Right? Would you react in the same way to the truck if it was parked? Obviously not! What properties does the moving truck have to make you react the way you do?

velocity – an indication of the speed and direction of an object in motion

The speed and direction that the truck and mosquito are moving in is called **velocity** (v). The rate at which velocity changes with respect to time is called **acceleration** (a).

acceleration – the rate at which velocity changes with respect to time; acceleration = change in velocity/time

The truck and mosquito both have a different mass. Recall that mass (m) is the quantity of material found in an object.

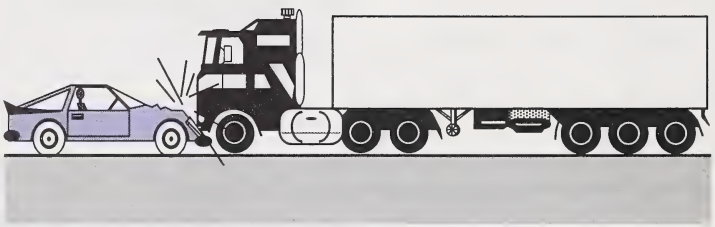
momentum – the quantity of motion of a body equal to the product of its mass and velocity

When mass and velocity are multiplied by each other, the product is a measure of the object's motion. This quantity of motion is called **momentum**. Its effect becomes extremely important during collisions. It can be calculated as follows:

momentum = mass × velocity = mv

The following diagrams and questions should help you to understand the concept of momentum.

Collision A



A small car and truck each travelling at 20 km/h in opposite directions collide head-on.

1. Predict the direction that the two vehicles will move after the collision.

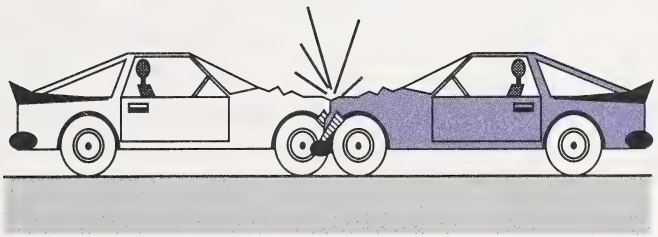
_____

2. Which vehicle has the most momentum in the collision? Why?

_____

_____

Collision B



Two identical cars each travelling at 30 km/h in opposite directions collide head-on.

3. Predict the direction that the two vehicles will move after the collision.

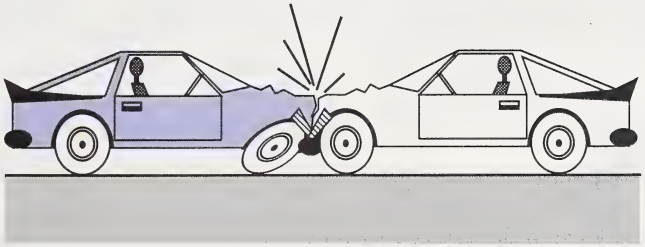
_____

4. Which vehicle has the most momentum in the collision? Why?

_____

_____

Collision C



A small car is travelling at 20 km/h and collides head-on with an identical car travelling at 60 km/h in the opposite direction.

5. Predict the direction that the two vehicles will move after the collision.

_____

6. Which vehicle has the most momentum in the collision? Why?

_____

_____

7. In Collision A, why did the truck have a greater momentum than the car if they were both travelling at the same speed?

_____

_____

_____

8. In Collision B, both cars had the same amount of motion with the same mass and velocity. Is it correct to say that both cars had the same momentum? Explain.

_____

_____

_____

Check your answers by turning to the Appendix, Section 3: Activity 2.

Activity 3: Conservation of Momentum

A vehicle with a large momentum will create a strong impact during a collision. But what happens after the collision?

Similar to the conservation of energy, momentum is also conserved.

The total momentum before impact is the same as the total momentum after impact. This means that momentum cannot be created or destroyed, but it may be transferred. This is known as the **law of conservation of momentum**.

law of conservation of momentum – a law stating that momentum cannot be created or destroyed

However, the law of conservation of momentum will be restricted only to vehicle collisions at this time. Calculations involving momentum will also be restricted to head-on collisions where the cars stay smashed together.

Head-on collisions involve cars travelling in opposite directions so velocity will be looked at carefully.

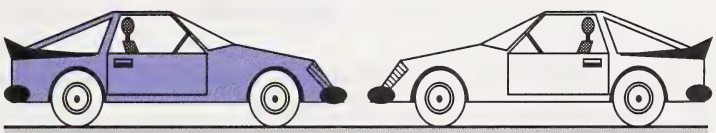
Showing Direction

In a mathematical number line, numbers to the right of 0 are positive and those to the left are negative.

You will use the same principle when dealing with the velocity of a given vehicle. All vehicles travelling to the right will be given a positive velocity. All vehicles travelling to the left will be given a negative velocity.

The following sequence of diagrams, questions, and collision calculation examples should help to explain what happens to momentum in mathematical terms.

Collision D



Car A	Car B
m = 2000 kg	m = 2000 kg
v = + 30 km/h	v = – 30 km/h

The two cars both have a 2000 kg mass. Both are travelling at the same speed, 30 km/h, but in opposite directions. The velocity of the car travelling to the right will be + 30 km/h, and the car travelling to the left will be – 30 km/h.

1. Predict what will happen to the two cars immediately after impact.

Calculation Example of Total Momentum Before Impact

Car A

momentum = mass × velocity
= 2000 kg × (+ 30 km/h)
= 60 000 kg•km/h

Car B

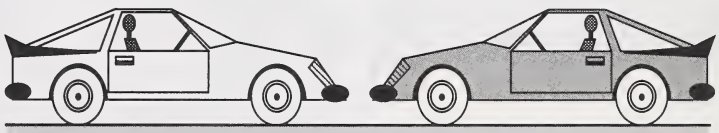
momentum = mass × velocity
= 2000 kg × (– 30 km/h)
= – 60 000 kg•km/h

Total Momentum = Momentum Car A + Momentum Car B

= 60 000 kg•km/h + (– 60 000 kg•km/h)
= 0 kg•km/h

The total momentum of 0 kg•km/h immediately after collision indicates that the cars have come to rest.

Collision E



Car A	Car B
m = 1500 kg	m = 1500 kg
v = + 60 km/h	v = – 100 km/h

The two vehicles both have a 1500 kg mass. Car A is travelling to the right with a velocity of + 60 km/h. Car B is travelling to the left with a velocity of – 100 km/h.

2. Predict what will happen after impact.

3. Calculate the individual momenta before impact.

   a. Car A:

   momentum = $m \times v$

   momentum = _____ × _____

   momentum = _____ kg•km/h

   b. Car B:

   momentum = $m \times v$

   momentum = _____ × _____

   momentum = _____ kg•km/h

   c. Now calculate the total momentum after impact.

   total momentum = momentum of Car A + momentum of Car B

   total momentum = _____ + _____

   total momentum = _____ kg•km/h

   d. Which direction are the cars going after impact? (Hint: Look at the sign of the total momentum.)

   _____

Check your answers by turning to the Appendix, Section 3: Activity 3.

If the total momentum is a positive number, the cars will be travelling to the right. If the number is negative, the cars will be travelling to the left. If the total momentum is 0, the cars will not travel in either direction.

Calculation Example of Velocity After Impact

If you use the basic momentum calculation formula where

$$\text{momentum} = \text{mass} \times \text{velocity},$$

and divide both sides of the formula by mass, you would obtain the formula for velocity where

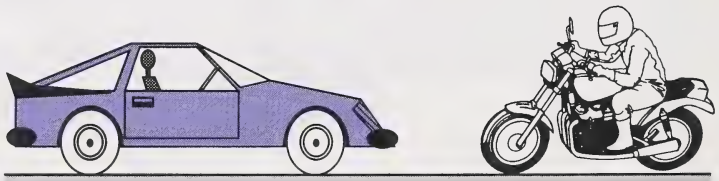
$$\text{velocity} = \frac{\text{momentum}}{\text{mass}}.$$

By using the previous total momentum calculations, velocity can now be calculated as follows:

$$\begin{aligned} \text{velocity} &= \frac{\text{total momentum}}{\text{total mass}} \\ &= \frac{-60\,000 \text{ kg} \cdot \text{km / h}}{6\,000 \text{ kg}} \\ &= -10 \text{ km / h} \end{aligned}$$

The negative velocity indicates that the two cars will be travelling towards the left after impact.

Collision F



Car A	Motorcycle
m = 2000 kg	m = 300 kg
v = + 25 km/h	v = – 60 km/h

The car has a mass of 2000 kg and is travelling to the right with a velocity of 25 km/h. The motorcycle has a mass of 300 kg and is travelling to the left with a velocity of – 60 km/h.

4. Calculate the individual momenta before impact.

   a. Momentum of Car A:

   momentum = $m \times v$

   momentum = _____ × _____

   momentum = _____ kg•km/h

   b. Momentum of a motorcycle:

   momentum = $m \times v$

   momentum = _____ × _____

   momentum = _____ kg•km/h

   c. Calculate the total momentum after impact.

   total momentum = momentum of car + momentum of motorcycle

   total momentum = _____ + _____

   total momentum = _____ kg•km/h

   d. Calculate the velocity and direction after impact.

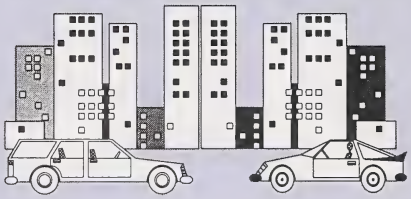
   $$\text{velocity} = \frac{\text{total momentum}}{\text{total mass}}$$

   direction of travel = _____

Check your answers by turning to the Appendix, Section 3: Activity 3.

Problem Calculation

Use the information in the following diagram to solve the problems.



Car A	Car B
m = 2500 kg	m = 1000 kg
v = + 30 km/h	v = – 70 km/h

Car A has a mass of 2500 kg and is travelling to the right with a velocity of 30 km/h. Car B has a mass of 1000 kg and is travelling to the left with a velocity of – 70 km/h.

5. Calculate the following:

   a. momentum of Car A before impact

   b. momentum of Car B before impact

c. total momentum after impact

d. velocity after impact

Check your answers by turning to the Appendix, Section 3: Activity 3.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

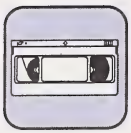
All things have energy. Energy can be classified into two different types: potential energy and kinetic energy. Potential energy refers to energy that is stored or the energy of an object due to its position. Kinetic energy refers to energy in an object due to its motion.

Momentum refers to a quantity of motion that is equal to the product of the mass and velocity of an object.

Energy and momentum are always conserved. This means that neither energy nor momentum can be created or destroyed, but they can be converted to other forms.

The momentum before a collision is equal to the momentum after a collision.

To review energy and momentum, do either Part A or Part B.



In Part A you will view a TV Ontario video, *Speed*. In Part B you will solve some problems involving momentum calculations.

Part A

View the video to get a better understanding of the relationship between velocity and momentum.

Part B

A 2000 kg car is travelling towards the right at a velocity of 90 km/h before colliding with a tree.

m = 2000 kg

v = + 90 km/h

1. How much momentum does the car have before colliding with the tree?

2. Since the car is in motion, it has kinetic energy. During the collision, what happens to the kinetic energy of the car?

_____

_____

_____

A 2000 kg car travels towards the right at a velocity of 10 km/h and collides head on with a truck travelling in the opposite direction at a velocity of – 4 km/h. The truck has a mass of 10 000 kg.

m = 2000 kg
v = 10 km/h

m = 10 000 kg
v = – 4 km/h

3. Calculate the following.

   a. momentum of car:

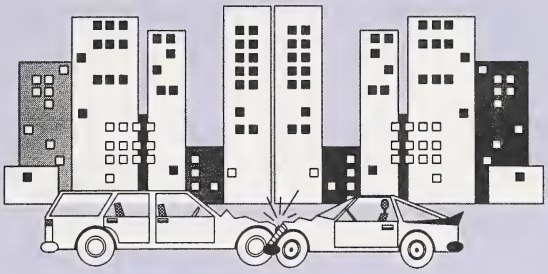
b. momentum of truck:

c. total momentum after impact:

d. velocity after impact:

e. direction of travel:

A 3000 kg car (Car A) travels towards the right at a velocity of 20 km/h and collides head-on with a 2000 kg car (Car B) travelling in the opposite direction at a velocity of – 40 km/h.



m = 2000 kg
v = 20 km/h

m = 1000 kg
v = – 40 km/h

4. Calculate the following.

   a. momentum of Car A before impact:

   b. momentum of Car B before impact:

c. total momentum after impact:

d. velocity after impact:

e. direction of travel:

Check your answers by turning to the Appendix, Section 3: Extra Help.

Enrichment

Do **one** of the following:

1. Prepare a short report discussing kinetic and potential energy of a tennis match. Be sure to discuss the energy of the tennis ball, tennis racquets, and the players.

2. Explain, in terms of kinetic and potential energy, why a ball does not bounce as high on a carpeted floor as it does on a concrete or wooden floor.

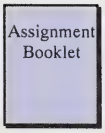
3. Devise your own momentum calculation for a rear-end collision involving two cars travelling in the same direction.

Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

An object in motion has kinetic energy. Potential energy refers to stored energy which has the potential to do work. Energy is never created or destroyed, but it is always conserved.

Momentum is the product of mass and velocity. Momentum is conserved.



ASSIGNMENT

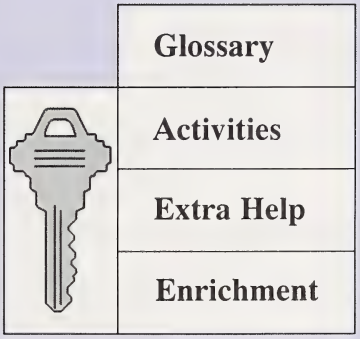
Turn to your Assignment Booklet and do the assignment for Section 3.

MODULE SUMMARY

Travelling in cars today poses some very real problems with safety and personal risk. These problems can be studied in a controlled environment and dealt with scientifically.

Laws of physics can provide you with many answers related to the motion of objects. When dealing with car crashes, there is more than one collision to worry about. The outcome of certain crashes can be predicted mathematically using established laws in physics.

Appendix



Glossary

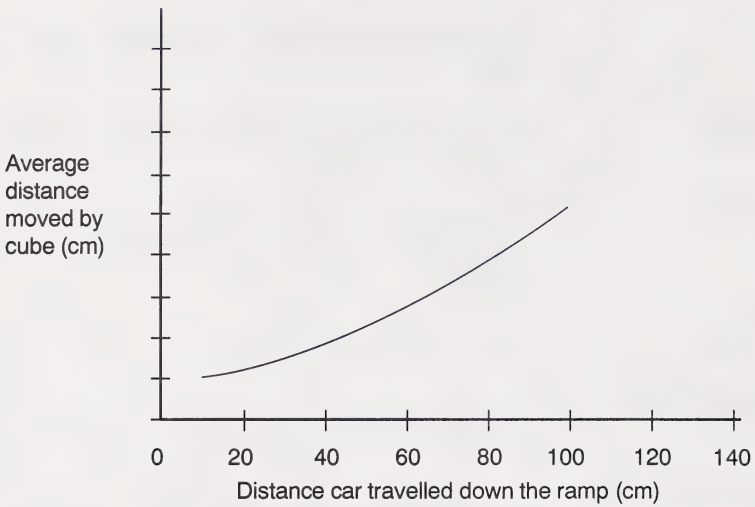
Acceleration	• the rate at which velocity changes with respect to time; acceleration = change in velocity/time
Energy	• the capacity to do work
Force	• a push or a pull that tends to change the position or motion of an object
Hydroplaning	• riding on a film of water collected between tires and road surface under special conditions
Inertia	• the tendency of an object to resist changes in motion The greater the mass, the greater the tendency to remain in motion or at rest
Kinetic energy	• energy of an object due to its motion
Law of conservation of energy	• a law stating that energy cannot be created or destroyed
Law of conservation of momentum	• a law stating that momentum cannot be created or destroyed
Mass	• a measure of the quantity of material found in an object; usually measured in grams or kilograms
Momentum	• the quantity of motion of a body equal to the product of its mass and velocity
Potential energy	• stored energy or energy or an object due to its position
Simulation	• an imitation of the real thing
Work	• a force applied to an object over a certain distance
Velocity	• an indication of the speed and direction of an object in motion

Suggested Answers

Section 1: Activity 1

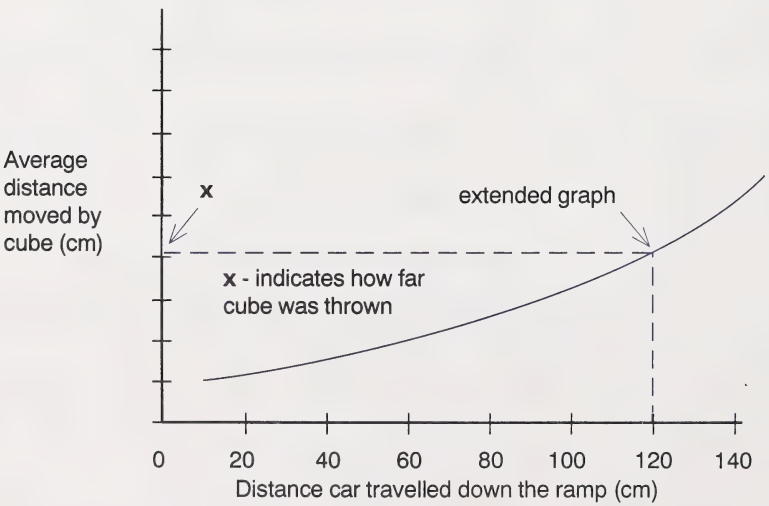
Investigation: Investigating Sudden Stops

1.



The graph should rise to the right. As the distance the car travelled down the ramp increased, the distance the cube moved should also have increased.

2.



Extend your graph in a smooth curve in the general direction it is going. Read the prediction from the graph and compare with the actual value you obtained.

3. The greater the speed, the greater the distance the cube was thrown.

Investigation: The Physics Behind the Magic

4. The coin follows the card when pulled slowly due to the force of friction. The coin should stay on the table when the card is pulled quickly due to the coin's inertia.

Section 1: Activity 2

1. The motorcyclist colliding with the rear of a moving car illustrates the first collision.

2. The motorcyclist could be thrown into the car or onto the pavement.

3. The motorcyclist would likely be thrown towards the car as an object in motion stays in motion unless acted upon by an outside force.

4. Because an object at rest stays at rest unless acted upon by an outside force, the head of the driver will tend to stay behind the body especially if there is no head rest on the seat. The head appears to go backwards and the result is whiplash, a serious neck injury.

Section 1: Activity 3

Investigation: The Force Required to Change Motion

1. The greater the mass of the car or can, the greater the distance the box was moved.

2. The larger car or can exerted more force than the smaller one.

3. The car will experience a greater change in motion as its mass is smaller than that of the truck.

Section 1: Follow-up Activities

Extra Help

Investigation: The Inertia of a Cork

1. The cork will appear to move in the opposite direction that the jar moved. This is due to its inertia. The cork remains at rest until the jar hits the cork and makes it move. The string may also be pulling the cork.

2. The cork moves towards the hand stopping the jar. An object in motion stays in motion unless acted upon by an outside force, namely the hand stopping the motion.

3. The cork moves away from you.

Enrichment

1. The cork moves in the direction the jar moves. This is opposite to the direction in the empty jar.

2. The cork moves away from the hand that stops the jar. Again, this is opposite to the direction in the empty jar.

3. The cork moves towards you – again opposite to the direction in the empty jar. The reason that things behave so differently when there was water in the jar can be explained if you think about what happens in a centrifuge. The more dense materials will be thrown further away from the centre. The less dense materials are found closer to the centre. Since the cork is less dense than the water it is closer to the centre and points towards you.

Section 2: Activity 1

Investigation: Safe Packaging

1. Answers may vary depending on container design. Your egg may have survived impact or it may have cracked or become scrambled.

2. Answers may vary. The second trial may be a duplicate of the first or it may be different. The egg may have survived, cracked, or become scrambled. Ideally the second trial should be more successful if using an improved design.

3. Answers may vary. Survival depends on secure packaging to absorb a sound collision safely. Breakage depends on ineffective packaging leading to second collision consequences.

4. The second collision cannot be eliminated, but the consequences can be prevented. If the egg survives, secure packaging prevents damage to the egg by preventing the consequences of a second collision.

Section 2: Activity 2

Investigation: Safe Packaging in Automobiles

1. The dummy was thrown against the sides of the milk carton when it was free to move.

2. The thread should have cut into the dummy because the thread is very thin.

3. The lap and shoulder belt work best to protect the passenger.

4. The balloon acted as an airbag – a safety feature found in more and more cars today.

Section 2: Activity 3

1. Some hazards that are beyond the driver's control are weather conditions, the physical condition of the road (i.e., potholes, loose gravel), and wildlife crossing the road.

2. Hydroplaning can be prevented by

   - reduced or moderate speed
   - good tire tread

3. Winter driving hazards include

   - heavy snowfall which reduces visibility and covers road boundaries
   - freezing rain which promotes skidding, increases stopping distance, and reduces traction
   - thick fog which reduces visibility akin to driving blindfolded
   - extreme cold which is a contributing factor to stalled vehicles

4. Summer driving hazards include

   - dust storms which reduce visibility
   - heavy downpour promoting skidding, increasing stopping distance, and reducing traction
   - loose gravel on the road contributing to loss of vehicle control
   - muddy secondary roads and potholes which promotes skidding and loss of vehicle control

   Both summer and winter hazards include night driving with reduced vision, temporary blindness from on-coming headlights, sunrise, or sunset; and collisions with animals unexpectedly crossing the road.

5. Unexpected circumstances and driver actions include

   - parked or stalled vehicles necessitating evasive action
   - slow moving vehicles, farm machinery, and recreation vehicles increase collision risk when attempting to pass them
   - loss of vehicle control from alcohol or drug use is often involved in tragic traffic accidents
   - collisions with animals unexpectedly crossing

6. There are probably fewer motorcycles on the highway than there are cars and trucks.

7. Scheduled airlines are the safest means of travel and passenger cars are the least safe.

8. The population of both countries or the number of vehicles in each country would need to be known.

Extra Help

1. Second collision refers to the occupants of a vehicle colliding with the interior of the vehicle.

2. • shoulder and lap belts (seat belts)
   • air bags
   • padded interior parts such as dash, doors, steering wheel
   • collapsing steering wheel
   • recessed door handles, power windows (no window handles)
   • head rests (reduce whiplash)

3. • shock absorbing bumpers

   • accordion frame and panels

   • very strong side frames (If vehicle was hit from the side, the doors used to cave right into the occupant of the cars which spread the impact over a larger part of the vehicle.)

Enrichment

Section 3: Activity 1

Investigation: Potential and Kinetic Energy

1. When the stretched elastic band is released, it moves through a distance.

2. No, the stretched elastic was not doing work because the force was not moving over a distance.

3. Yes, the stretched elastic was doing work. A force moved over a distance as the elastic began to resume its unstretched position.

4. The car on top of the hill has more potential energy because it has the ability to release more kinetic energy as it rolls down the hill.

5. No, some of the car's kinetic energy does work by leaving tire skid marks and producing heat and sound from bending metal when the car hits the pole.

Section 3: Activity 2

1. The two vehicles will move towards the left after impact.

2. The truck has more momentum due to its larger mass.

3. The two vehicles will stop immediately after impact.

4. Neither vehicle has more momentum due to identical speed and mass.

5. The cars will move in the same direction in which the car that has more velocity was travelling.
6. The car travelling towards the left has greater momentum due to its greater speed.
7. The truck has a much larger mass than the car.
8. Yes, both cars have the same momentum due to identical mass and velocity.

Section 3: Activity 3

1. The two cars will stop immediately after impact.
2. The cars will travel towards the left after impact.
3. a. momentum of Car A

   momentum = $m \times v$

   momentum = **1 500** kg × **60** km/h

   momentum = **90 000** kg•km/h

   b. momentum of Car B

   momentum = $m \times v$

   momentum = **1 500** kg × **– 100** km/h

   momentum = **– 150 000** kg•km/h

   c. total momentum = momentum of Car A + momentum of Car B

   total momentum = **90 000** kg•km/h + (**– 150 000** kg•km/h)

   total momentum = **– 60 000** kg•km/h

   d. The cars will be travelling to the left due to negative momentum

4. a. momentum of a car:

momentum = $m \times v$

momentum = **2 000** kg × **25** km/h

momentum = **50 000** kg•km/h

b. momentum of motorcycle

momentum = $m \times v$

momentum = **300** kg × (**– 60** km/h)

momentum = **– 18 000** kg•km/h

c. total momentum = momentum of car + momentum of motorcycle

total momentum = **50 000** kg•km/h + (**– 18 000** kg•km/h)

total momentum = **32 000** kg•km/h

d.
$$\text{velocity} = \frac{\text{total momentum}}{\text{total mass}}$$
$$= \frac{\mathbf{32\,000}\ \text{kg•km/h}}{\mathbf{2\,300}\ \text{kg}}$$
$$= \mathbf{13.9}\ \text{km/h}$$

direction of travel = **towards the right due to positive velocity**

5. a. momentum = $m \times v$

momentum = 2 500 kg × 30 km/h

momentum = 75 000 kg•km/h

b. momentum of car B before impact

momentum = $m \times v$

momentum = 1 000 kg × (– 70 km/h)

momentum = – 70 000 kg•km/h

c. total momentum = momentum of Car A + momentum of Car B

total momentum = 75 000 kg•km/h + (– 70 000 kg•km/h)

total momentum = 5 000 kg•km/h

d. $$\text{velocity} = \frac{\text{total momentum}}{\text{total mass}}$$

$$= \frac{5\,000 \text{ kg•km/h}}{3\,500 \text{ kg}}$$

= 1.4 km / h towards the right due to positive velocity

Section 3: Follow-up Activities

Extra Help

Part B

1. momentum = $m \times v$

= 2 000 kg × 90 km/h

= 180 000 kg•km/h

2. Some of the kinetic energy of the car is transferred to the tree. The tree can be damaged or even broken. Some of the kinetic energy of the car is used to deform the car (parts are bent or broken).

3. a. momentum of car:

momentum $= m \times v$

$= 2\,000 \text{ kg} \times 10 \text{ km/h}$

$= 20\,000 \text{ kg•km/h}$

b. momentum of truck:

momentum $= m \times v$

$= 10\,000 \text{ kg} \times (-4 \text{ km/h})$

$= -40\,000 \text{ kg•km/h}$

c. total momentum after impact

total momentum = momentum of car + momentum of truck

$= 20\,000 \text{ kg•km/h} + (-40\,000 \text{ kg•km/h})$

$= -20\,000 \text{ kg•km/h}$

d. velocity after impact:

$$\text{velocity} = \frac{\text{total momentum}}{\text{toal mass}}$$

$$= \frac{-20\,000 \text{ kg•km/h}}{12\,000 \text{ kg}}$$

$$= -1.7 \text{ km/h}$$

e. direction of travel:

The negative velocity indicates that the vehicles will be travelling towards the left.

4. a. momentum of car A before impact

momentum = $m \times v$

momentum = 2 000 kg × 20 km/h

momentum = 40 000 kg•km/h

b. momentum of car B before impact

momentum = $m \times v$

momentum = 1 000 kg × (– 40 km/h)

momentum = – 40 000 kg•km/h

c. total momentum = momentum of Car A + momentum of Car B

total momentum = 40 000 kg•km/h + (– 40 000 kg•km/h)

total momentum = 0 kg•km/h

d. $$\text{velocity} = \frac{\text{total momentum}}{\text{total mass}}$$

$$= \frac{0 \text{ kg•km/h}}{3\,000 \text{ kg}}$$

$$= 0 \text{ km/h}$$

e. Zero velocity indicates the vehicles are stopped exactly where they collided.

Enrichment

1. Answers will vary. However any movement by the players, ball, or tennis racket would possess kinetic energy. Potential energy would be present in the ball, tennis racket, or players during the time when there is no movement on their part. This would most likely occur during the split second these objects are at rest or just prior to any movement being made. What may not be apparent is the transformation of energy from one form to another during any of these actions unless photographed in slow motion.

2. Using kinetic and potential energy only in the explanation, it would be expected that your answer would include the fact that a carpeted floor absorbs more kinetic energy than a concrete or wooden floor. The ball also loses more potential energy as it bounces from a carpeted floor than from a concrete or wooden floor. Therefore, the ball would not bounce as high. The cycle repeats itself until all energy is spent.

3. Calculations will vary. You should find that the total momentum will be equal to the sum of the two individual momenta. You should find that the speed of the two cars after the collision is somewhere between the two original speeds. That is, faster than the slower, front vehicle and slower than the faster, rear vehicle.

NOTES

NOTES

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